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To: Dr. D. Mills
Director of Research

EFFECT OF DENSITY OF PRAWNS ON THEIR GROWTH AND SURVIVAL

S.A. Bartlett
Mathematician

T.C. Olivares
Mathematician

Reliability & Statistics Section
Operations Research Department

ABSTRACT

The analysis reveals that there is a statistically significant effect of the density of pre-maturation prawns on their growth and survival. Incremental changes in mean weight and biomass decrease as initial density and initial mean weight increases. In most instances, the survival rate tends to decrease as initial density increases. Results for post-maturation prawns do not indicate any clear dependence of growth and survival on density except that survival decreases for large prawns.

1. INTRODUCTION

The Biology Section of the Chemical Research Department has been conducting experiments to study methods of raising prawns (large freshwater shrimp) efficiently and economically. The purpose is to make commercial use of the warm water available near Ontario Hydro's generating stations, in which prawns could adapt well. Prawns are of particular interest because they are a premium priced food product; they also have a rapid growth rate and are easy to raise in captivity.

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It is economical to raise as many prawns as possible in as small a space as possible. Thus, it is important to study the effect of density of prawns on their growth rate and survival, with the objective to determine which density gives the best yield at the least cost. A statistical analysis of a study to assess this effect is presented in this report.

2. THE DATA

Four experiments were conducted, each at eight week intervals. Three densities of prawns were examined in each experiment and will be referred to as low, medium and high densities. The prawns were eight weeks post-larvae at the start of the study. A description of each experiment follows.

In the initial experiment, prawns were placed in nine cages of equal size (two cubic meters) in the same pool of water. The prawns were divided into three cages each of low, medium and high densities. Table 1 contains the initial numbers of prawns per cage for each experiment. The prawns were weighed at week 0 and again at week 8. It was not practical to ensure that initial and final weights were matched to the individual prawns. The number of prawns were counted in each cage at week 8 to obtain the survival rate per cage.

At week 8 the prawns were put together then divided by weight into two size groups, small and large. The criteria for dividing the prawns was such that the researchers decided which densities they wanted to study for small and large prawns, then divided the prawns into the small and large groups according to the availability. Prawns in each of the resulting size groups were divided into six cages; two cages each for low, medium and high densities. The two cages were put in separate pools.

At week 16, the prawns were put together again then divided by weight into three size groups; small, medium and large. For small and medium sizes, prawns were divided into six cages; two cages each for low, medium and high densities. The large prawns were kept in cages at low density with two replicates. The two cages were put in separate pools.

At week 24, the prawns were once again put together then divided into two size groups; small and large. For each group, the prawns were divided into six cages; two cages each for low, medium and high densities. The two cages were put in separate pools.

3. ANALYSIS

The four experiments were analyzed separately since they were not independent of each other and therefore could not be combined for one analysis. The lack of independence stems from the fact that no attempt was made to keep the same prawns in the same density situations throughout the study. For example, a prawn that was in a low density cage in weeks 0 to 8 may have been placed in a high density cage in weeks 8 to 16.

Ideally, the prawns should have been drawn from a very large pond for each stage of the experiment. However, no such pond was available. Thus, there is the potential for carry-over effects from an experiment to subsequent experiments. Accounting for these carry-over effects was beyond the scope of the analysis.

Three stages of analyses were done. First, an assessment of the standard deviations of the final weights were studied to determine if a transformation was required. Second, analyses of the individual weights were done to determine if there were statistical differences between densities. Third, the change in mean weights, change in biomass, and survival rates were modelled in terms of initial density and initial mean weights. Biomass is defined as the sum of the weights of all of the prawns in the cage.

The standard deviations were assessed graphically as a function of final mean weights. Dependence indicates that a transformation is required.

The individual weights were analyzed using analysis of variance. Density and replicate were included as factors. The analyses were done separately for each size since the low, medium and high densities were not the same for each size group of prawns.

In the 0-8 week experiment, the replicate cages were all in the same pool making the cages nested within density. Thus, a nested analysis of variance was used to analyze this experiment. Two-way analysis of variance was used to analyze the other 3 experiments. Replicates are the same as pools since the two pools are the two replicates.

Modelling of the change in mean weights, survival rates and change in biomass was done using regression techniques. The resulting models can be used for prediction.

Prawns in cages with mean initial weights of less than 14 grams were classified as pre-maturation prawns. All others were classified as post-maturation prawns. Post-maturation prawns were large prawns in the 16 to 24 week experiment and all prawns in the 24 to 32 week experiment. It was expected that the results for these two groups would be different and thus were treated separately.

4. RESULTS

4.1 Standard Deviations

The standard deviations of the initial weights per cage within each size and experiment group are shown in Figure 1, indicating that initial conditions are similar within each group. Standard deviations of the final weights per cage appeared to increase with the mean of the final weights (Figure 2). This dependence violates the criteria necessary for analysis of variance of the final weights, namely, that the variation should be constant for all groups within each experiment. To compensate, the data were transformed using the natural logarithm of the weight plus one. One was added so that the transformation of weight zero is zero. Figure 3 shows the standard deviation versus mean of the transformed final weights. The standard deviations do not appear to increase with mean within each experiment. Therefore, the analysis on the individual weights was done using the transformed data.

There does not appear to be any correlation between the standard deviations of the initial and final transformed weights (Figure 4). Thus, the final standard deviations only depend on their final mean weight.

4.2 Mean Weights

Two analyses of the mean weights were done. First, the analysis of the individual weights was done to determine if density affected growth, and second, the percent change in mean weight per cage was modelled with respect to initial density and size.

4.2.1 *Analysis of Individual Weights*

Tables of descriptive statistics for initial weights and final weights for each cage of prawns are contained in Attachment I. Box plots of the weights are also given.

Table 2 contains the results of the analysis of the individual final weights. The final weights were transformed to be the difference between the ln (natural logarithm) of the final weight plus one and the ln of the initial mean weight of the cage plus one. The individual final weights were adjusted for the initial mean weights to enable relative comparisons. There were significant differences in the change in weights among densities for the 0 to 8 week experiment, for both small and large prawns in the 8 to 16 week experiment, and for small and medium prawns of the 16 to 24 week experiment. No significant differences among densities were detected for post-maturation prawns.

There was a significant difference among replicates for the 0 to 8 week experiment. Otherwise there were no significant differences among replicates for any other experiment. The small prawns of the 16 to 24 week experiment was the only experiment exhibiting a significant interaction between replicates and density. These results indicate that a statistical dependence exists between density and growth of prawns. Therefore, the next step was to model the growth as a function of density.

4.2.2. *Modelling of Mean Weights*

The fractional change in weights was modelled in terms of initial density and initial mean weight. The fractional change is defined as the difference between the final and initial mean weights of the cage divided by the initial mean weight of the cage. A plot of this measure against the ln of the initial number of prawns in the cage is given in Figure 5 for pre-maturation prawns. In general, it appears that the fractional change gets smaller as density increases and as the prawns get older and bigger.

As a matter of interest, a plot of the absolute change in mean weight is given in Figure 6. Here, the change in weight appears to get smaller as the densities get smaller but gets larger as the prawns age and initial weights get larger. The fractional change in weight is more meaningful since it is adjusted for the initial weights of the prawns. Thus statistical modelling was done of the fractional change.

The variation of the fractional change in mean weight appears to widen as density increases (Figure 5). To stabilize the variation, the ln of the fractional change in mean weight plus one was taken and plotted against the natural log of the initial number of prawns for both pre-

maturation and post-maturation prawns (Figures 7 and 8, respectively). The variation in the data appears more even in Figure 7 than in Figure 5. The modelling was therefore done of the transformed fractional change in mean weight.

Each experiment was treated separately. The transformed fractional change in mean weight was modelled as a function of the natural log of the initial number of prawns per cage and the natural log of the initial mean weight. Table 3 contains the results. Significant models were obtained for each experiment except for the 24 to 32 week experiment. This is consistent with the results in Table 1. In each of the first three experiments the change in weight decreased as the initial density of prawns increased and as the initial mean weight increased. No trends were detected for the 24 to 32 week experiment.

4.3 Survival Rates

Plots of survival rates versus the initial number of prawns per cage for pre-maturation and post-maturation prawns are given in Figures 9 and 10, respectively. The survival rates were modelled as a function of the natural log of the initial number of prawns and the natural log of the initial mean weight.

Table 4 contains the results of the modelling. In the 0 to 8 week experiment, survival was only a function of the log of initial density (there was only one size category). In the 8 to 16 week experiment, the survival did not appear to depend on the initial density but only on the initial mean size. The reason for this is more clear in Figure 9. The survival rate for small prawns increased with initial density, then decreased slightly. The decrease in survival rate was small for large prawns as the initial density increased. Thus initial density did not prove to be a statistically significant factor. For the 16 to 24 week experiment, survival rate decreased with initial mean size and initial density. For the 24 to 32 week experiment, the survival rate decreased with initial density only for large prawns.

4.4 Biomass

Figure 11 contains a plot of the relationship between the change in biomass standardized by the initial biomass and the initial number of prawns per cage. Intuitively, this is a more meaningful measure of the increase in biomass. The plot shows that the biomass increases less rapidly as the density of prawns increases.

Since the variation clearly increases as the change in biomass increases, the natural logarithm was taken of both variables. Figure 12 shows that the variation has evened out and thus more reliable conclusions will be obtained from the analyses.

Table 5 contains the resulting models. For the 0 to 8 week experiment, the change in biomass decreases as initial density increases. For the 8 to 16 and the 16 to 24 week experiments, the change in biomass decreases as both the initial mean weight and the initial density increases. No significant model was detected for the 24 to 32 week experiment (Figure 13).

5. CONCLUSIONS

From the analyses performed on the prawn data, the following conclusions are made.

- Although initial standard deviations tend to be similar within each size and experiment group, final standard deviations tend to increase as the final means increase.
- The fractional change in mean weights tends to decrease as the initial density and initial mean weight increase for pre-maturation prawns. No trends were detected for post-maturation prawns.
- The survival rate tends to decrease as initial density increases. This trend occurs in all experiments except for the 8 to 16 week experiment and for the small prawns in the 24 to 32 week experiment.
- The fractional change in biomass tends to decrease as the initial density increases for pre-maturation prawns. No trends were detected for post-maturation prawns.

Note: The models should only be used as an indication of the effect of density on growth and survival within the ranges given. They should not be used to extrapolate conclusions beyond the ranges of the data.

Approved:

A.H. Chung
Manager
Operations Research Dept

Submitted:

S.A. Bartlett
Mathematician
Reliability & Statistics Section
Operations Research Dept

T.C. Olivares
Mathematician
Reliability & Statistics Section
Operations Research Dept

SAB/TCO:cmh

TABLE 1

INITIAL DENSITY PER CAGE FOR EACH EXPERIMENT

Experiment	Density	Size	Replicate	Initial Density	Final Density
0 - 8 Weeks	Low	-	1	150	132
			2	150	141
			3	150	191
	Medium		1	300	232
			2	300	239
			3	300	207
	High		1	450	277
			2	450	317
			3	450	309
8 - 16 Weeks	Low	Small	1	74	56
			2	74	58
	Medium		1	150	124
			2	150	132
	High		1	225	184
			2	224	174
	Low	Large	1	49	36
			2	49	39
	Medium		1	100	68
			2	100	71
	High		1	151	100
			2	150	103
16 - 24 Weeks	Low	Small	1	50	33
			2	50	34
	Medium		1	92	49
			2	88	58
	High		1	139	75
			2	129	57
	Low	Medium	1	45	23
			2	45	27
	Medium		1	65	38
			2	65	27
	High		1	87	35
			2	87	31
	Low	Large	1	40	13
			2	48	14
24 - 32 Weeks	Low	Small	1	10	0
			2	10	4
	Medium		1	40	4
			2	30	2
	High		1	50	3
			2	50	7
	Low	Large	1	10	3
			2	10	2
	Medium		1	18	1
			2	20	2
	High		1	30	1
			2	30	2

TABLE 2

ANALYSIS OF INDIVIDUAL WEIGHTS FOR
EACH EXPERIMENT AND EACH SIZE GROUP

Note: Table contains p-values for each test.

Experiment	Size	Factors		Density * Replicate
		Density	Replicate	
0 - 8 weeks	-	0.0001	0.0066(1)	-
8 - 16 weeks	small	0.0001	0.0840	0.1164
	large	0.0001	0.6923	0.1430
16 - 24 weeks	small	0.0001	0.3536	0.0002
	medium	0.0408	0.3441	0.7045
	large	-	0.6908(2)	-
24 - 32 weeks	small	0.8242	0.9687	0.3869
	large	0.4861	0.5545	0.5887

Notes:

(1) Model is a nested model

(2) Model only has replicate factor

TABLE 3

MODELS OF THE CHANGE IN MEAN WEIGHTS OF PRAWNS FOR EACH EXPERIMENT

Note: The dependent variable is $y = ln\ ((m_f - m_i)/m_i + 1)$ where m_f = mean final weight per cage (grams) and m_i = mean initial weight per cage (grams)

Experiment	Number of Points	Model	Model Significance	R^2
0 - 8 weeks	9	$y = 3.517 - 0.242\ ln_i$	0.0003	0.86
8 - 16 weeks	12	$y = 3.177 - 0.624\ lm_i - 0.270\ ln_i$	0.0001	0.92
16 - 24 weeks	12	$y = 2.385 - 0.450\ lm_i - 0.174\ ln_i$	0.0008	0.80
24 - 32 weeks	12	no significant model		

where ln_i = ln of initial number per cage
lm_i = ln of initial mean weight per cage (grams)

TABLE 4

MODELS OF SURVIVAL RATES OF PRAWNS PER CAGE
FOR EACH EXPERIMENT

Note: The dependent variable is $y = n_f/n_i$
where n_f is the final number per cage and n_i is the initial number per cage

Experiment	Number of Points	Model	Model Significance	R^2
0 - 8 weeks	9	$y = 1.793 - 0.183\ ln_i$	0.0030	0.74
8 - 16 weeks	12	$y = 1.043 - 0.195\ lm_i$	0.0042	0.58
16 - 24 weeks	12	$y = 2.253 - 0.407\ lm_i - 0.187\ lm_i$	0.0097	0.64
24 - 32 weeks	6	$y = 0.704 - 0.196\ ln_i$ (1)	0.0202	0.79

where ln_i = ln of initial number per cage
lm_i = ln of initial mean weight per cage (grams)

(1) for large prawns only

TABLE 5

MODELS FOR CHANGE IN BIOMASS OF PRAWNS PER CAGE FOR EACH EXPERIMENT

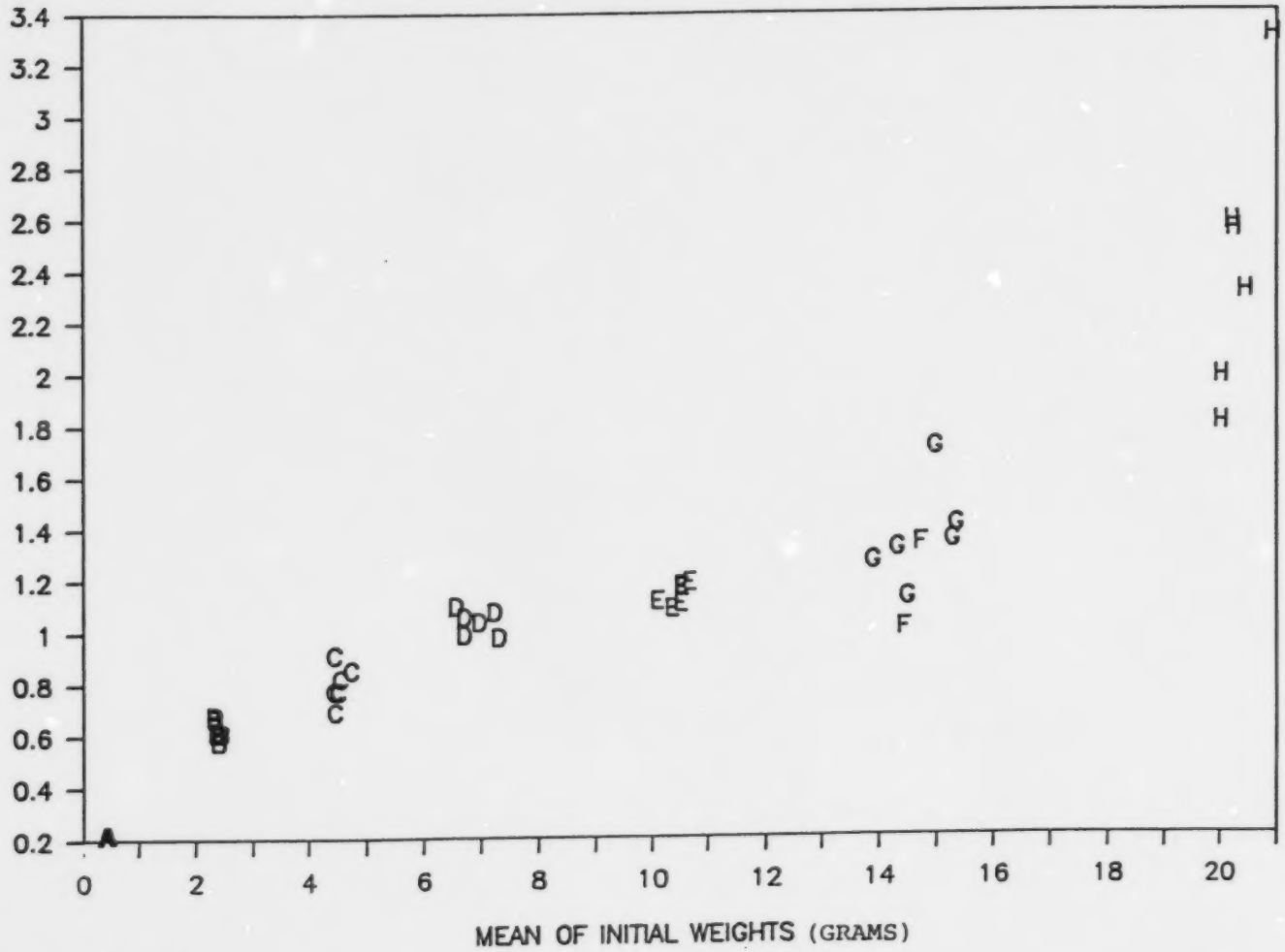
Note: The dependent variable is $y = ln\ ((b_f - b_i)/b_i + 1)$
where b_f = final biomass per cage (grams) and bi = initial biomass per cage (grams)

Experiment	Number of Point	Model	Model Significance	R^2
0 - 8 weeks	9	$y = 4.577 - 0.480\ ln_i$	0.0002	0.88
8 - 16 weeks	12	$y = 3.469 - 0.907\ lm_i - 0.303\ ln_i$	0.0001	0.95
16 - 24 weeks	12	$y = 5.058 - 1.244\ lm_i - 0.531\ ln_i$	0.0001	0.88
24 - 32 weeks	12	no significant model		

where ln_i = ln of initial number per cage
lm_i = ln of iniial mean weight per cage (grams)

FIGURE 1

STANDARD DEVIATIONS VS MEANS OF INITIAL
WEIGHTS FOR EACH EXPERIMENT AND SIZE GROUP

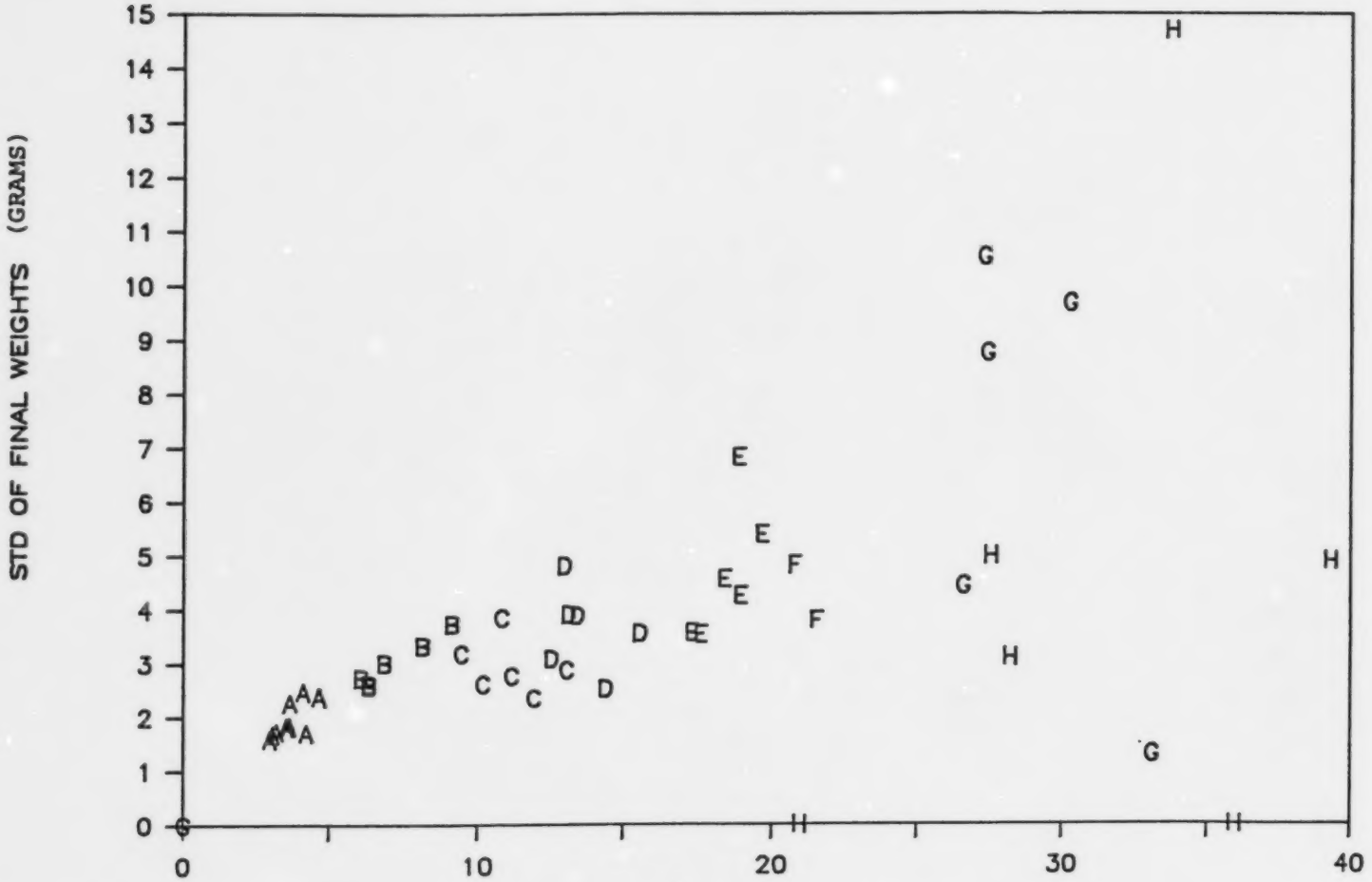


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 2

STANDARD DEVIATIONS VS MEANS OF FINAL WEIGHTS
FOR EACH EXPERIMENT AND SIZE GROUP

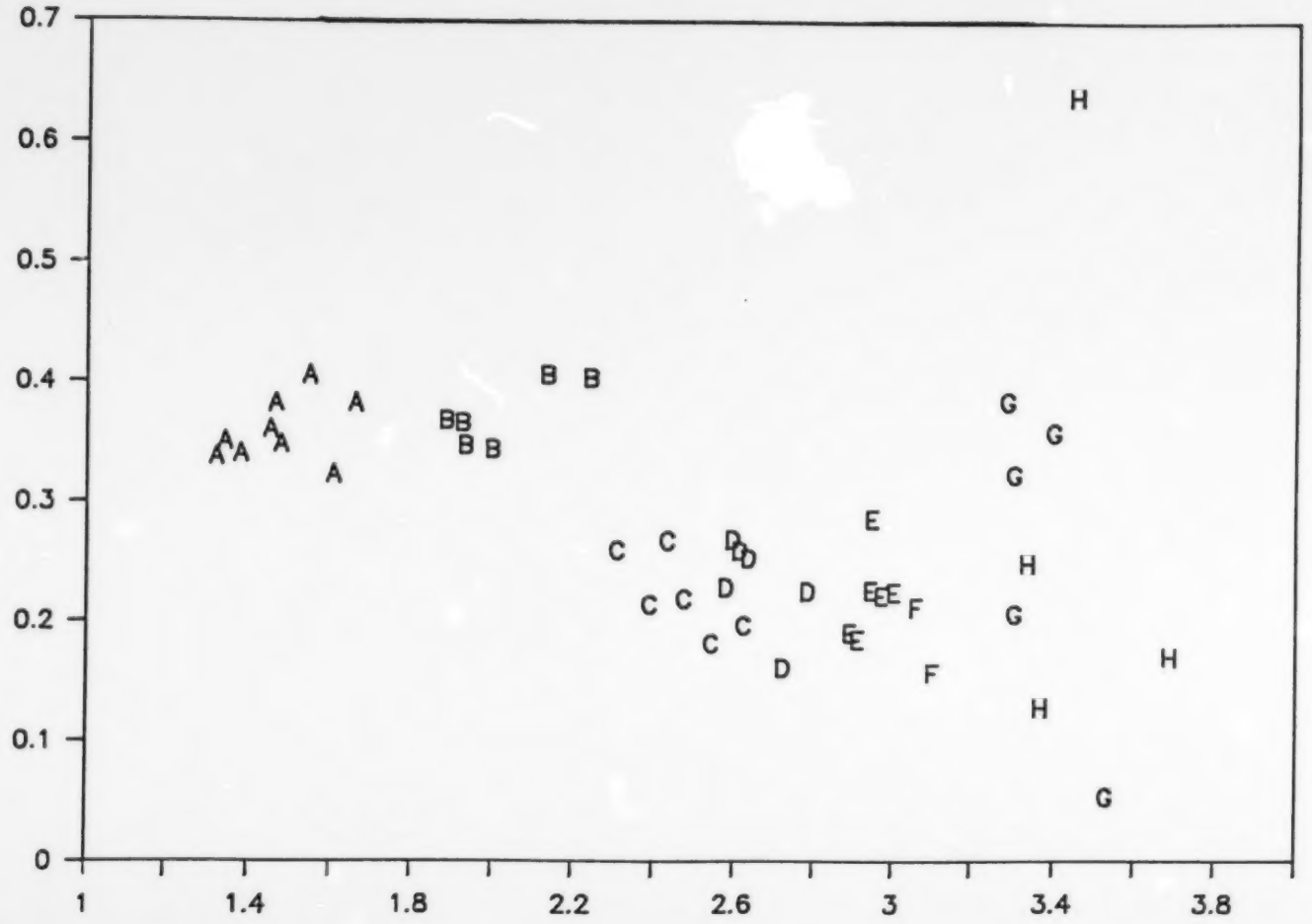


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 3

STANDARD DEVIATIONS VS MEANS OF TRANSFORMED
FINAL WEIGHTS FOR EACH EXPERIMENT AND SIZE GROUP

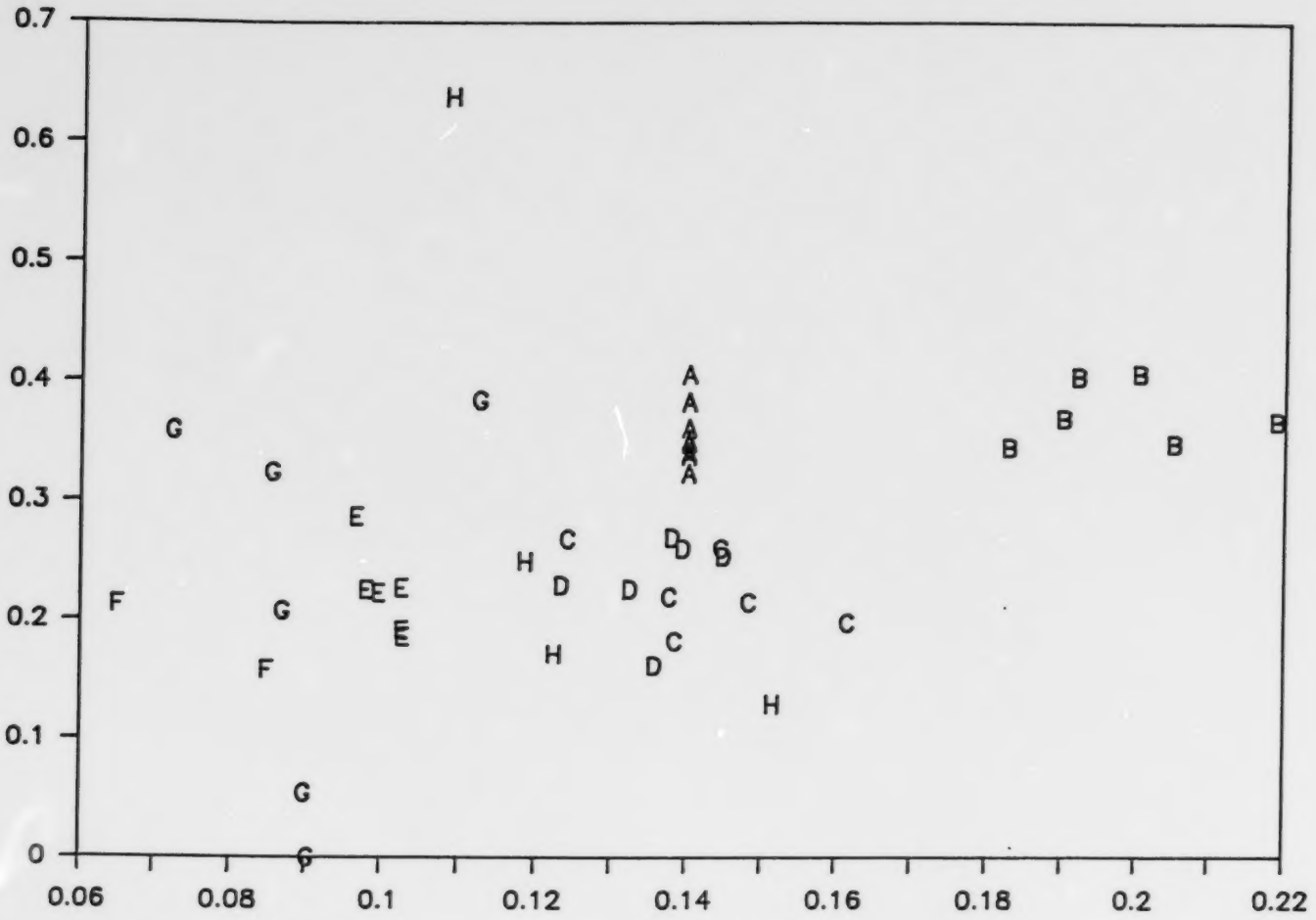


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 4

STANDARD DEVIATIONS OF TRANSFORMED FINAL WEIGHTS
VS STANDARD DEVIATIONS OF TRANSFORMED INITIAL WEIGHTS
FOR EACH EXPERIMENT AND SIZE GROUP

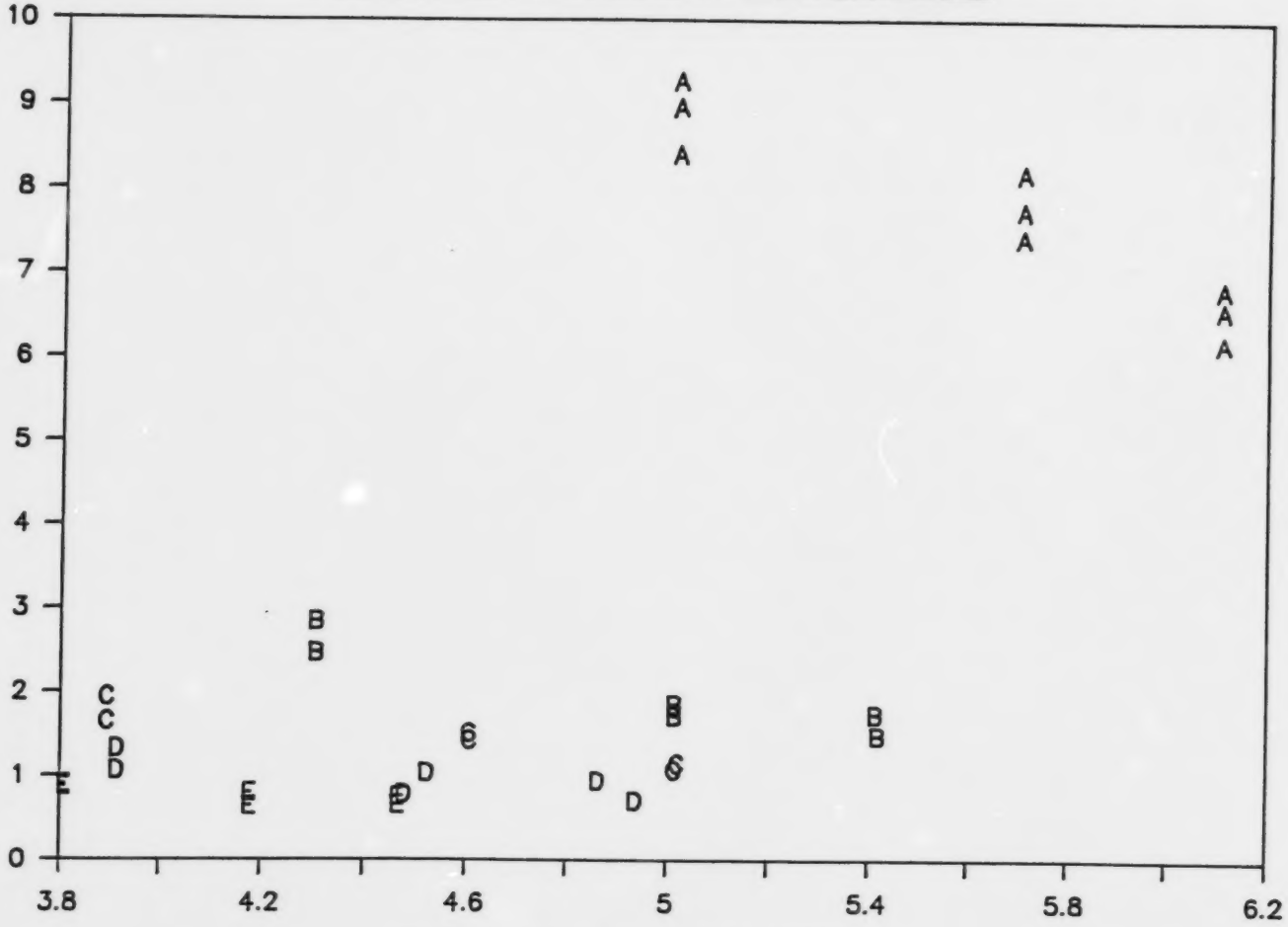


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 5

STANDARDIZED CHANGE IN MEAN WEIGHTS VS
INITIAL DENSITY FOR PRE-MATURATION PRAWNS

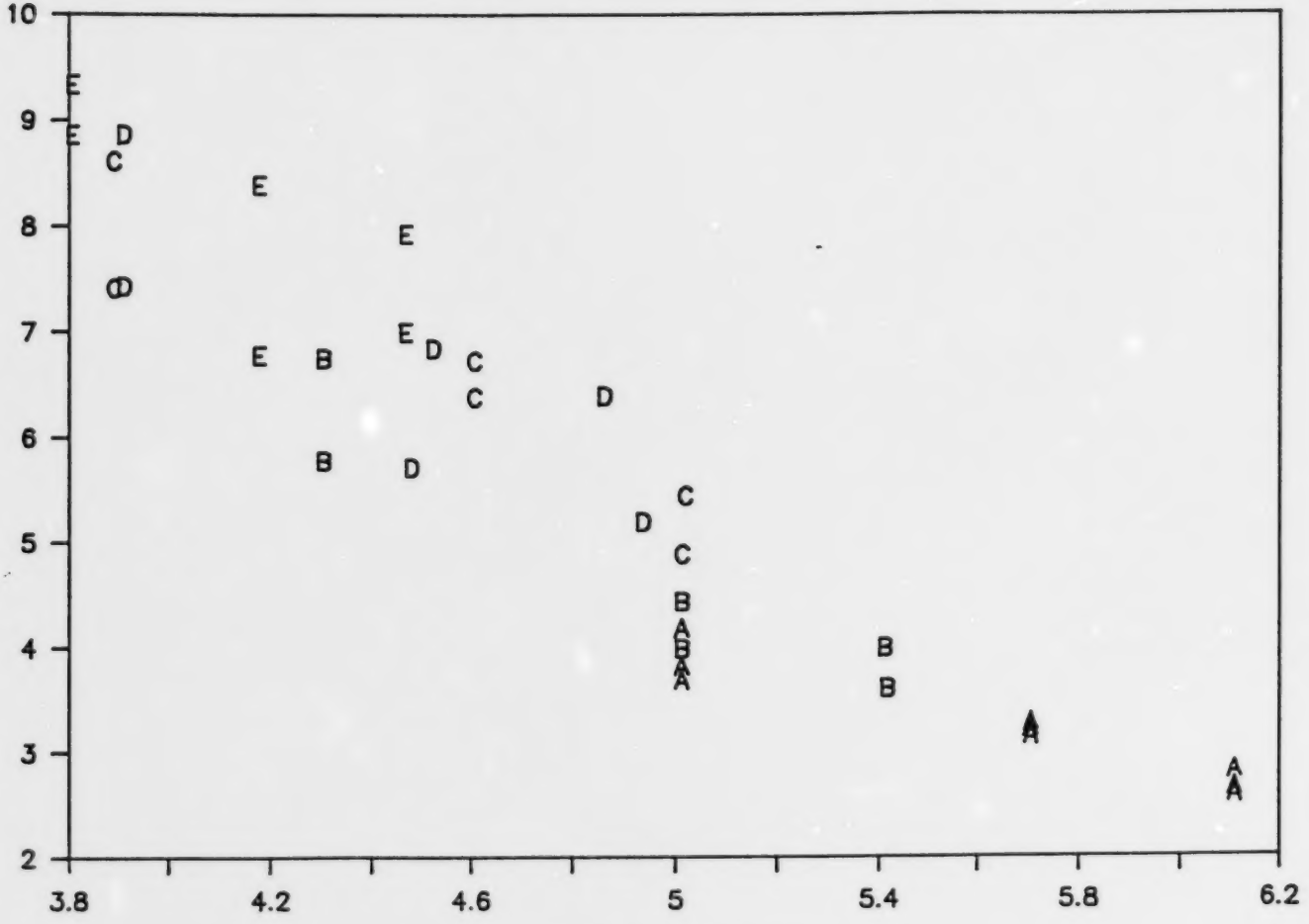


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 6

CHANGE IN MEAN WEIGHT VS INITIAL DENSITY
FOR PRE-MATURATION PRAWNS

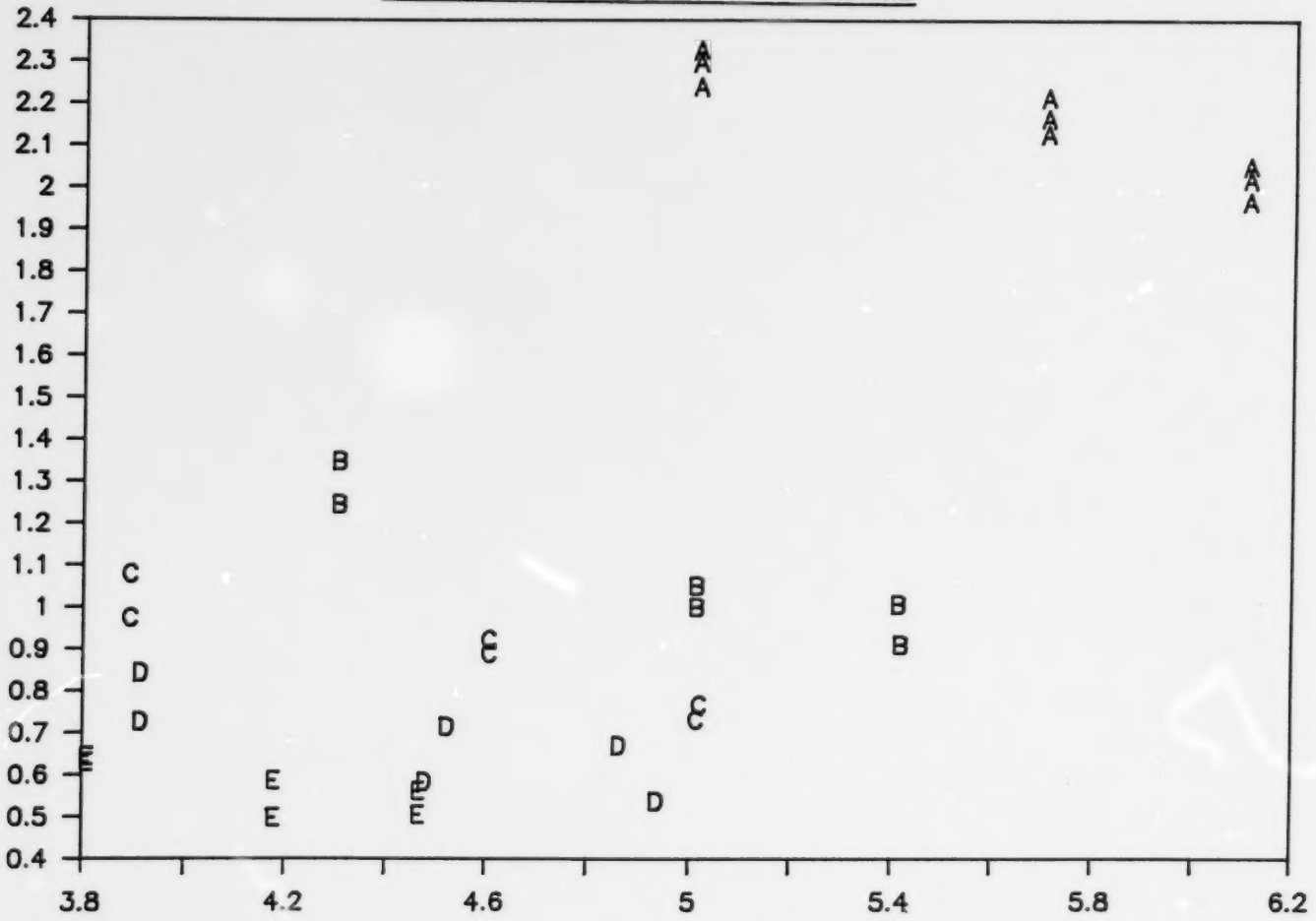


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 7

LOG OF STANDARDIZED CHANGE
IN MEAN WEIGHTS VS INITIAL
DENSITY FOR PRE-MATURATION PRAWNS

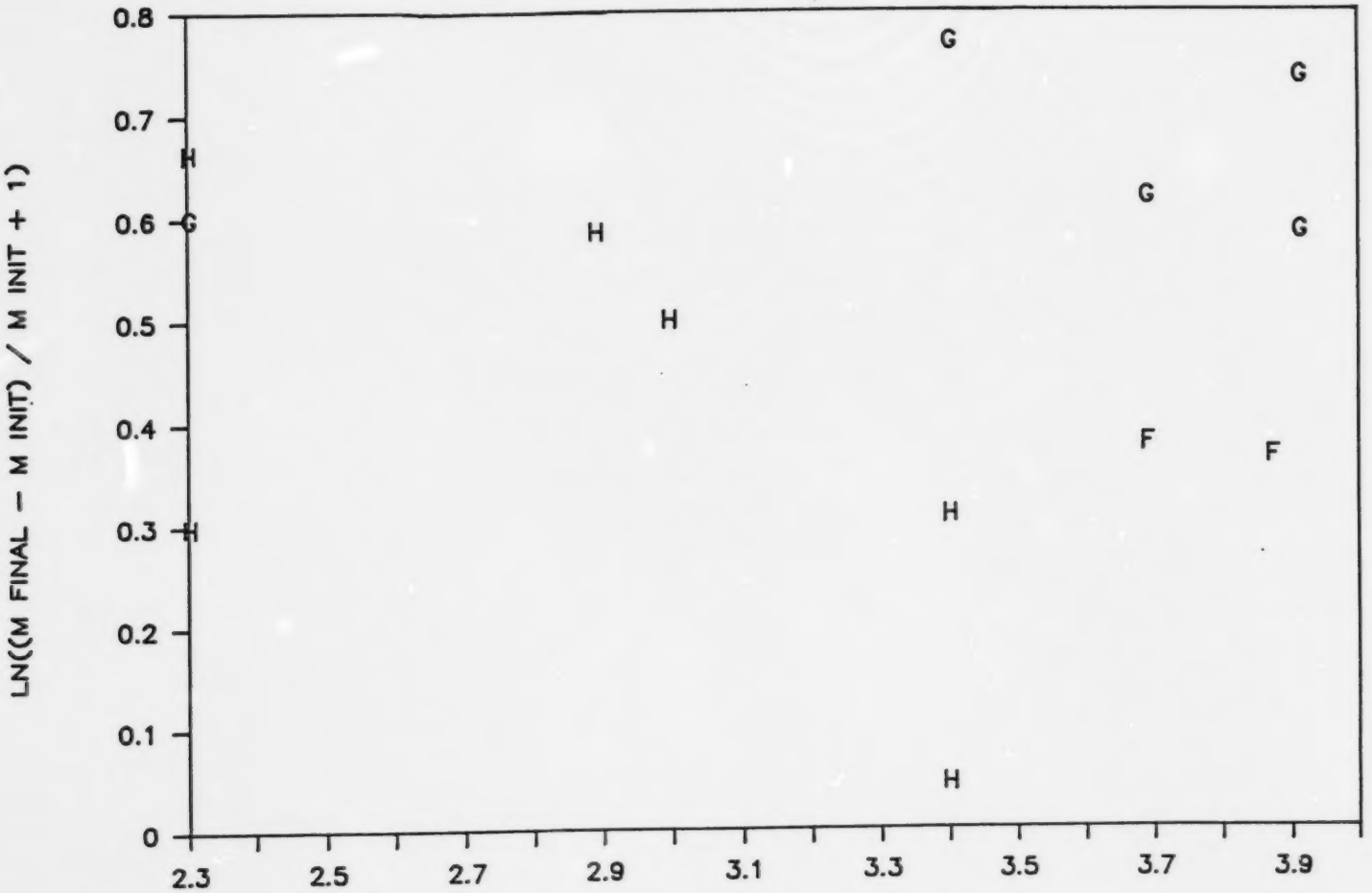


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 8

LOG STANDARDIZED CHANGE IN
MEAN WEIGHTS VS INITIAL DENSITY
FOR POST-MATURATION PRAWNS

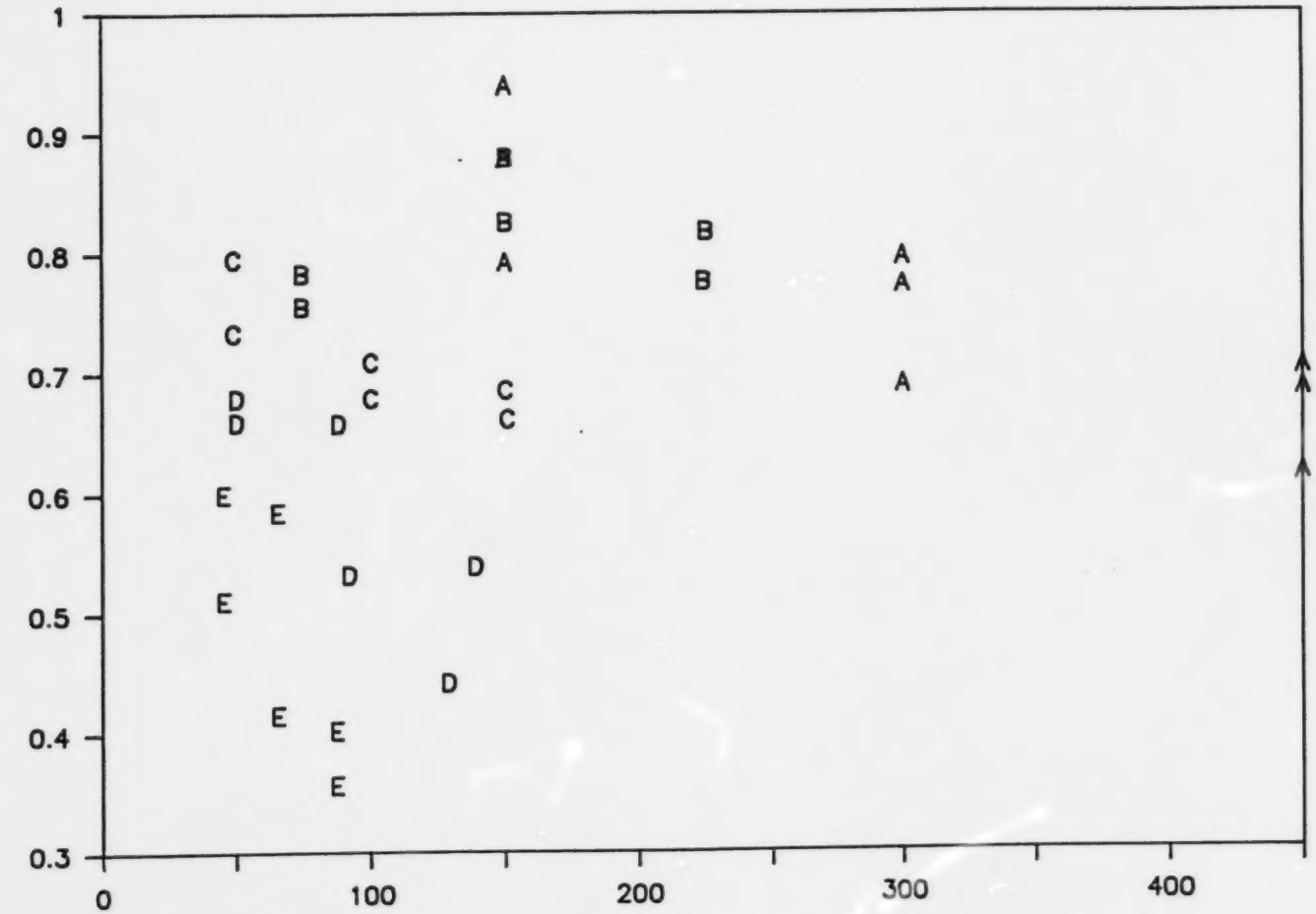


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 9

SURVIVAL RATE VS INITIAL
DENSITY FOR PRE-MATURATION PRAWNS

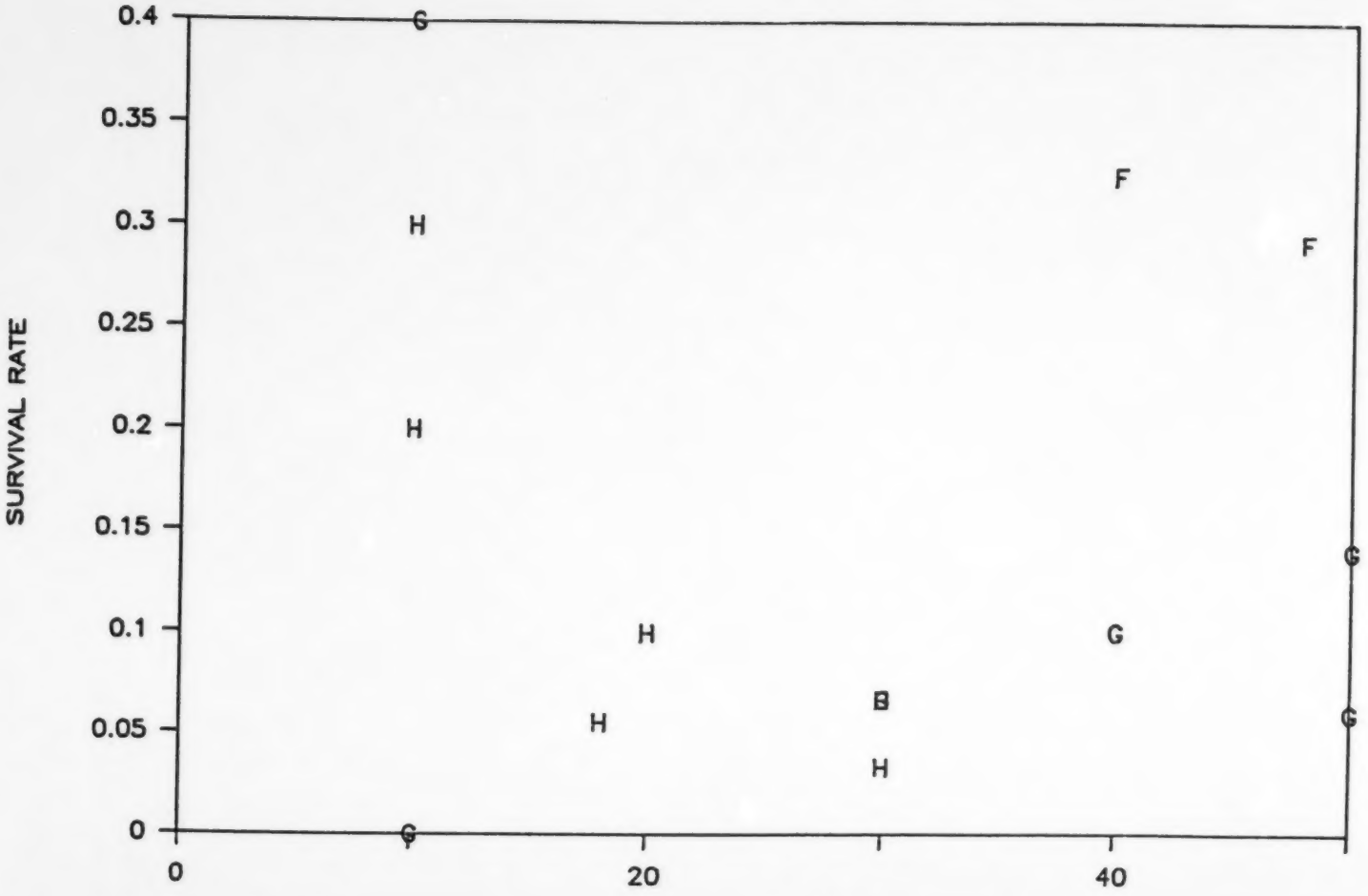


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 10

SURVIVAL RATE VS INITIAL
DENSITY FOR POST-MATURATION PRAWNS

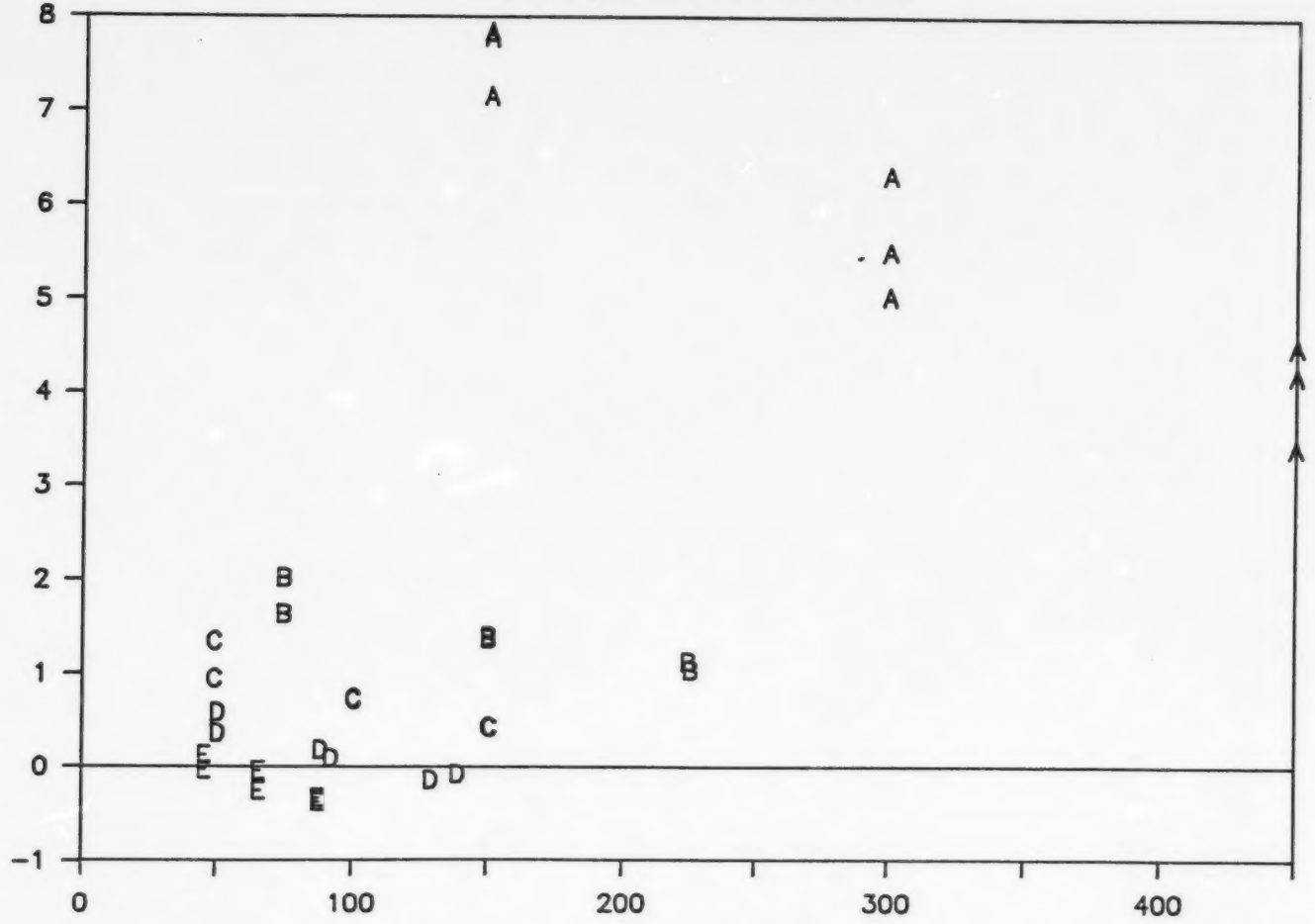


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 11

STANDARDIZED CHANGE IN
BIOMASS VS INITIAL DENSITY
FOR PRE-MATURATION PRAWNS



Legend

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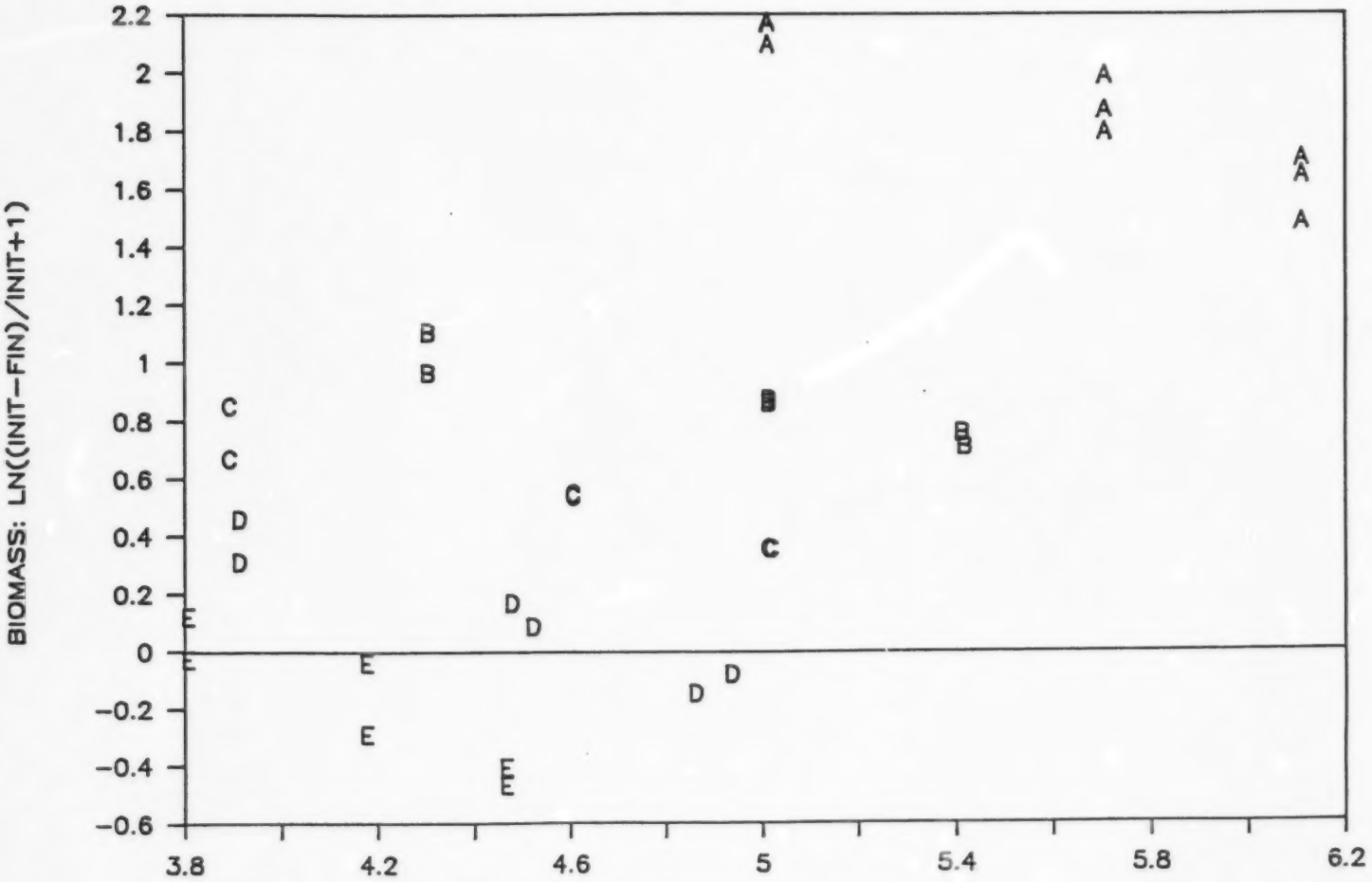
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 12

TRANSFORMED STANDARDIZED CHANGE IN
BIOMASS VS INITIAL DENSITY FOR PRE-MATURATION PRAWNS

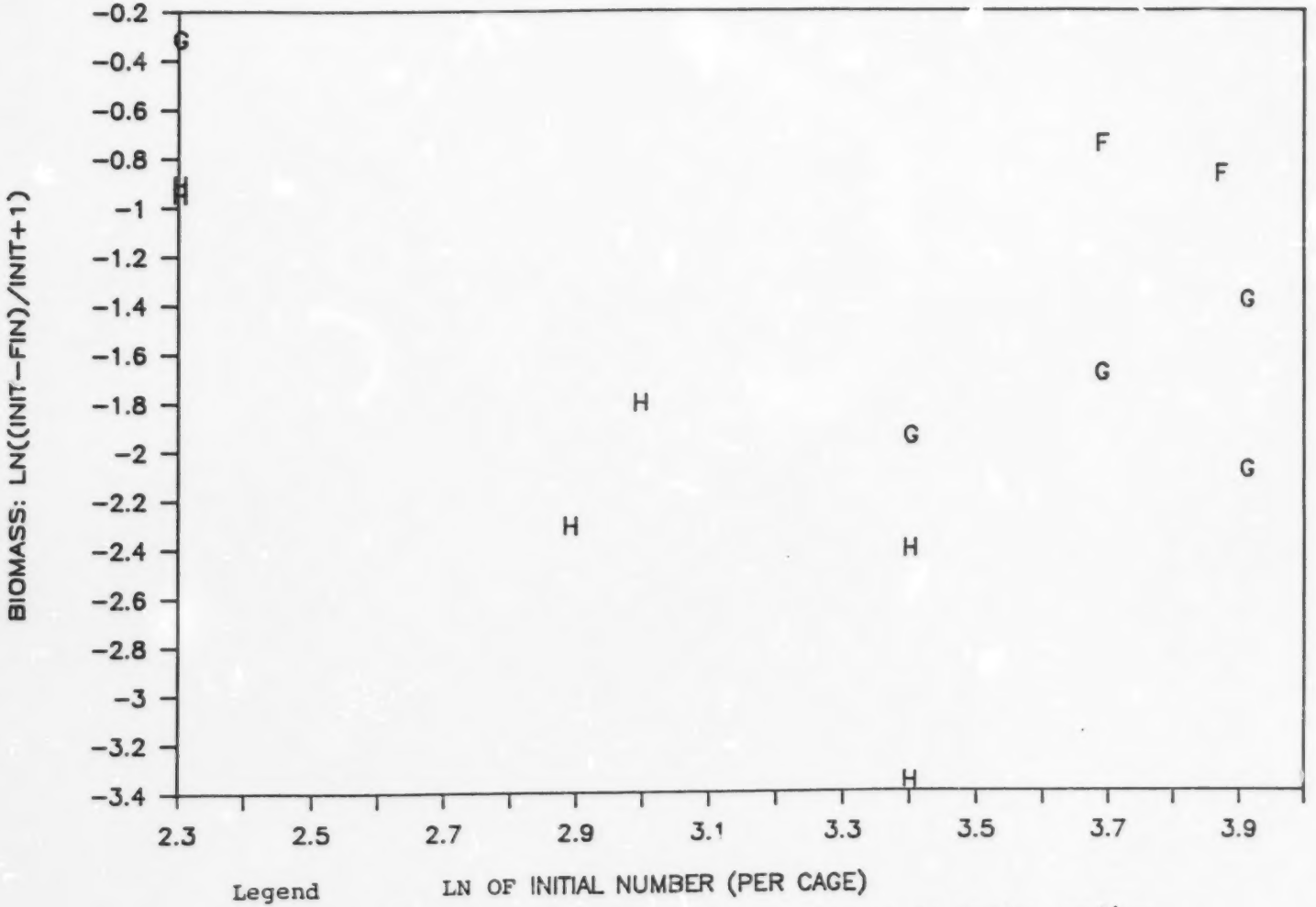


Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

FIGURE 13

TRANSFORMED STANDARDIZED CHANGE IN BICMASS
VS INITIAL DENSITY FOR POST-MATURATION PRAWNS



Legend

A = 0-8 weeks
B = 8-16 weeks, small
C = 8-16 weeks, large
D = 16-24 weeks, small
E = 16-24 weeks, medium
F = 16-24 weeks, large
G = 24-32 weeks, small
H = 24-32 weeks, large

ATTACHMENT I

DESCRIPTIVE STATISTICS AND BOX PLOTS FOR PRAWN EXPERIMENTS

TABLE A1

DESCRIPTIVE STATISTICS FOR
ORIGINAL AND TRANSFORMED
WEIGHTS OF THE 0-8 WEEK EXPERIMENT

NOTE: S = SIZE D = DENSITY R = REPLICATE

FINAL RAW DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	132	4.67	2.39	14.70	1.10	3.05	4.00	5.90
2	1	1	2	141	4.13	2.48	17.20	1.00	2.50	3.70	5.10
3	1	1	3	119	4.25	1.72	10.20	1.30	2.90	4.10	5.20
4	1	2	1	232	3.67	1.84	15.10	1.00	2.40	3.45	4.40
5	1	2	2	239	3.69	2.27	23.50	0.90	2.20	3.20	4.50
6	1	2	3	207	3.56	1.82	14.60	0.80	2.30	3.30	4.20
7	1	3	1	277	3.09	1.68	16.90	0.80	2.00	2.80	3.70
8	1	3	2	317	3.24	1.73	16.50	0.80	2.20	2.90	3.80
9	1	3	3	309	2.98	1.60	14.10	0.80	1.90	2.70	3.70

FINAL LOG DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	132	1.43	0.48	2.69	0.10	1.12	1.39	1.77
2	1	1	2	141	1.28	0.52	2.84	0.00	0.92	1.31	1.63
3	1	1	3	119	1.36	0.41	2.32	0.26	1.06	1.41	1.65
4	1	2	1	232	1.19	0.46	2.71	0.00	0.88	1.24	1.48
5	1	2	2	239	1.17	0.50	3.16	-0.11	0.79	1.16	1.50
6	1	2	3	207	1.16	0.48	2.68	-0.22	0.83	1.19	1.44
7	1	3	1	277	1.01	0.48	2.83	-0.22	0.69	1.03	1.31
8	1	3	2	317	1.06	0.46	2.80	-0.22	0.79	1.06	1.34
9	1	3	3	309	0.98	0.47	2.65	-0.22	0.64	0.99	1.31

TABLE A2

DESCRIPTIVE STATISTICS FOR ORIGINAL AND TRANSFORMED WEIGHTS OF THE 8-16 WEEK EXPERIMENT

NOTE: S = SIZE D = DENSITY R = REPLICATE

INITIAL RAW DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	74	2.33	0.63	3.40	0.80	1.90	2.40	2.80
2	1	1	2	74	2.36	0.61	3.40	1.00	2.00	2.35	2.90
3	1	2	1	150	2.38	0.59	3.50	0.80	2.00	2.40	2.90
4	1	2	2	150	2.32	0.67	5.20	0.90	1.80	2.30	2.80
5	1	3	1	225	2.42	0.61	3.40	1.00	2.00	2.50	2.90
6	1	3	2	224	2.30	0.68	3.50	0.80	1.90	2.30	2.85
7	2	1	1	49	4.49	0.78	6.50	3.50	3.80	4.20	5.10
8	2	1	2	49	4.43	0.92	6.50	3.50	3.70	4.00	5.10
9	2	2	1	100	4.42	0.77	6.80	3.50	3.80	4.35	4.90
10	2	2	2	100	4.44	0.69	6.20	3.50	3.90	4.30	4.90
11	2	3	1	151	4.72	0.85	6.50	2.90	4.00	4.60	5.30
12	2	3	2	150	4.52	0.83	6.50	3.40	3.80	4.30	5.10

FINAL RAW DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	56	8.11	3.36	15.50	2.10	5.50	8.10	10.30
2	1	1	2	58	9.12	3.76	22.20	2.60	6.60	9.20	11.00
3	1	2	1	124	6.83	3.02	27.40	1.50	5.05	6.50	8.20
4	1	2	2	132	6.32	2.59	18.60	2.00	4.25	6.35	7.80
5	1	3	1	184	6.04	2.74	18.50	1.80	4.10	5.50	7.60
6	1	3	2	174	6.30	2.62	17.70	2.10	4.40	6.20	7.90
7	2	1	1	36	11.90	2.38	19.50	7.00	10.70	11.80	13.30
8	2	1	2	39	13.04	2.92	22.10	7.70	10.70	12.80	14.10
9	2	2	1	68	11.15	2.78	20.80	6.10	9.30	10.65	12.45
10	2	2	2	71	10.82	3.88	31.00	5.30	8.30	10.60	12.10
11	2	3	1	100	10.17	2.62	19.70	5.90	8.50	9.65	11.25
12	2	3	2	103	9.42	3.20	28.90	3.90	7.70	8.70	10.60

INITIAL LOG DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	74	0.80	0.30	1.22	-0.22	0.64	0.88	1.03
2	1	1	2	74	0.82	0.29	1.22	0.00	0.69	0.85	1.06
3	1	2	1	150	0.83	0.27	1.25	-0.22	0.69	0.88	1.06
4	1	2	2	150	0.80	0.30	1.65	-0.11	0.59	0.83	1.03
5	1	3	1	225	0.85	0.28	1.22	0.00	0.69	0.92	1.06
6	1	3	2	224	0.78	0.34	1.25	-0.22	0.64	0.83	1.05
7	2	1	1	49	1.49	0.17	1.87	1.25	1.34	1.44	1.63
8	2	1	2	49	1.47	0.20	1.87	1.25	1.31	1.39	1.63
9	2	2	1	100	1.47	0.17	1.92	1.25	1.34	1.47	1.59
10	2	2	2	100	1.48	0.15	1.82	1.25	1.36	1.46	1.59
11	2	3	1	151	1.54	0.18	1.87	1.06	1.39	1.53	1.67
12	2	3	2	150	1.49	0.18	1.87	1.22	1.34	1.46	1.63

FINAL LOG DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	56	1.99	0.48	2.74	0.74	1.70	2.09	2.33
2	1	1	2	58	2.12	0.46	3.10	0.96	1.89	2.22	2.40
3	1	2	1	124	1.84	0.41	3.31	0.41	1.62	1.87	2.10
4	1	2	2	132	1.76	0.41	2.92	0.69	1.45	1.85	2.05
5	1	3	1	184	1.70	0.44	2.92	0.59	1.41	1.70	2.03
6	1	3	2	174	1.75	0.44	2.87	0.74	1.48	1.82	2.07
7	2	1	1	36	2.46	0.20	2.97	1.95	2.37	2.47	2.59
8	2	1	2	39	2.54	0.21	3.10	2.04	2.37	2.55	2.65
9	2	2	1	68	2.38	0.24	3.03	1.81	2.23	2.37	2.52
10	2	2	2	71	2.33	0.29	3.43	1.67	2.12	2.36	2.49
11	2	3	1	100	2.29	0.24	2.98	1.77	2.14	2.27	2.42
12	2	3	2	103	2.20	0.29	3.36	1.36	2.04	2.16	2.36

TABLE A3

DESCRIPTIVE STATISTICS FOR ORIGINAL AND TRANSFORMED WEIGHTS OF THE 16-24 WEEK EXPERIMENT

NOTE: S = SIZE D = DENSITY R = REPLICATE

INITIAL RAW DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	74	2.33	0.63	3.40	0.80	1.90	2.40	2.80
2	1	1	2	74	2.36	0.61	3.40	1.00	2.00	2.35	2.90
3	1	2	1	150	2.38	0.59	3.50	0.80	2.00	2.40	2.90
4	1	2	2	150	2.32	0.67	5.20	0.90	1.80	2.30	2.80
5	1	3	1	225	2.42	0.61	3.40	1.00	2.00	2.50	2.90
6	1	3	2	224	2.30	0.68	3.50	0.80	1.90	2.30	2.85
7	2	1	1	49	4.49	0.78	6.50	3.50	3.80	4.20	5.10
8	2	1	2	49	4.43	0.92	6.50	3.50	3.70	4.00	5.10
9	2	2	1	100	4.42	0.77	6.80	3.50	3.80	4.35	4.90
10	2	2	2	100	4.44	0.69	6.20	3.50	3.90	4.30	4.90
11	2	3	1	151	4.72	0.85	6.50	2.90	4.00	4.60	5.30
12	2	3	2	150	4.52	0.83	6.50	3.40	3.80	4.30	5.10

FINAL RAW DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	56	8.11	3.36	15.50	2.10	5.50	8.10	10.30
2	1	1	2	58	9.12	3.76	22.20	2.60	6.60	9.20	11.00
3	1	2	1	124	6.83	3.02	27.40	1.50	5.05	6.50	8.20
4	1	2	2	132	6.32	2.59	18.60	2.00	4.25	6.35	7.80
5	1	3	1	184	6.04	2.74	18.50	1.80	4.10	5.50	7.60
6	1	3	2	174	6.30	2.62	17.70	2.10	4.40	6.20	7.90
7	2	1	1	36	11.90	2.38	19.50	7.00	10.70	11.80	13.30
8	2	1	2	39	13.04	2.92	22.10	7.70	10.70	12.80	14.10
9	2	2	1	68	11.15	2.78	20.80	6.10	9.30	10.65	12.45
10	2	2	2	71	10.82	3.88	31.00	5.30	8.30	10.60	12.10
11	2	3	1	100	10.17	2.62	19.70	5.90	8.50	9.65	11.25
12	2	3	2	103	9.42	3.20	28.90	3.90	7.70	8.70	10.60

INITIAL LOG DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	74	0.80	0.30	1.22	-0.22	0.64	0.88	1.03
2	1	1	2	74	0.82	0.29	1.22	0.00	0.69	0.85	1.06
3	1	2	1	150	0.83	0.27	1.25	-0.22	0.69	0.88	1.06
4	1	2	2	150	0.80	0.30	1.65	-0.11	0.59	0.83	1.03
5	1	3	1	225	0.85	0.28	1.22	0.00	0.69	0.92	1.06
6	1	3	2	224	0.78	0.34	1.25	-0.22	0.64	0.83	1.05
7	2	1	1	49	1.49	0.17	1.87	1.25	1.34	1.44	1.63
8	2	1	2	49	1.47	0.20	1.87	1.25	1.31	1.39	1.63
9	2	2	1	100	1.47	0.17	1.92	1.25	1.34	1.47	1.59
10	2	2	2	100	1.48	0.15	1.82	1.25	1.36	1.46	1.59
11	2	3	1	151	1.54	0.18	1.87	1.06	1.39	1.53	1.67
12	2	3	2	150	1.49	0.18	1.87	1.22	1.34	1.46	1.63

FINAL LOG DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	56	1.99	0.48	2.74	0.74	1.70	2.09	2.33
2	1	1	2	58	2.12	0.46	3.10	0.96	1.89	2.22	2.40
3	1	2	1	124	1.84	0.41	3.31	0.41	1.62	1.87	2.10
4	1	2	2	132	1.76	0.41	2.92	0.69	1.45	1.85	2.05
5	1	3	1	184	1.70	0.44	2.92	0.59	1.41	1.70	2.03
6	1	3	2	174	1.75	0.44	2.87	0.74	1.48	1.82	2.07
7	2	1	1	36	2.46	0.20	2.97	1.95	2.37	2.47	2.59
8	2	1	2	39	2.54	0.21	3.10	2.04	2.37	2.55	2.65
9	2	2	1	68	2.38	0.24	3.03	1.81	2.23	2.37	2.52
10	2	2	2	71	2.33	0.29	3.43	1.67	2.12	2.36	2.49
11	2	3	1	100	2.29	0.24	2.98	1.77	2.14	2.27	2.42
12	2	3	2	103	2.20	0.29	3.36	1.36	2.04	2.16	2.36

TABLE A4

DESCRIPTIVE STATISTICS FOR ORIGINAL AND TRANSFORMED WEIGHTS OF THE 24-32 WEEK EXPERIMENT

NOTE: S = SIZE D = DENSITY R = REPLICATE

INITIAL RAW DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	10	13.88	1.34	15.70	12.10	12.50	13.85	14.90
2	1	1	2	10	14.96	1.81	17.80	12.50	13.80	14.75	16.20
3	1	2	1	40	14.31	1.33	16.90	12.30	13.15	14.35	15.15
4	1	2	2	30	15.32	1.43	17.50	12.40	14.60	15.40	16.20
5	1	3	1	50	14.48	1.14	17.10	13.00	13.50	14.30	15.10
6	1	3	2	50	15.25	1.37	17.50	12.40	14.30	15.30	16.40
7	2	1	1	10	20.93	3.49	27.40	17.90	18.10	19.40	24.80
8	2	1	2	10	20.25	2.69	24.60	17.60	18.30	19.05	23.20
9	2	2	1	18	20.02	2.04	24.10	17.30	18.30	19.80	21.80
10	2	2	2	20	20.46	2.37	25.40	17.60	18.35	20.75	22.05
11	2	3	1	30	20.02	1.83	23.30	17.40	18.20	19.85	21.30
12	2	3	2	30	20.22	2.62	25.90	17.70	17.90	19.20	22.50

FINAL RAW DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	0							
2	1	1	2	4	27.28	12.15	45.00	18.40	19.46	22.85	35.10
3	1	2	1	4	26.57	5.12	29.42	18.89	23.93	28.98	29.21
4	1	2	2	2	33.10	1.85	34.40	31.79	31.79	33.10	34.40
5	1	3	1	3	30.25	11.83	43.70	21.43	21.43	25.62	43.70
6	1	3	2	7	27.39	9.45	43.20	17.10	18.98	25.00	35.84
7	2	1	1	3	28.22	3.82	32.27	24.68	24.68	27.71	32.27
8	2	1	2	2	39.32	6.91	44.20	34.43	34.43	39.32	44.20
9	2	2	1	1	35.97		35.97	35.97	35.97	35.97	35.97
10	2	2	2	2	33.75	20.80	48.45	19.04	19.04	33.75	48.45
11	2	3	1	1	20.95		20.95	20.95	20.95	20.95	20.95
12	2	3	2	2	27.54	7.05	32.52	22.55	22.55	27.54	32.52

INITIAL LOG DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	10	2.63	0.10	2.75	2.49	2.53	2.63	2.70
2	1	1	2	10	2.70	0.12	2.88	2.53	2.62	2.69	2.79
3	1	2	1	40	2.66	0.09	2.83	2.51	2.58	2.66	2.72
4	1	2	2	30	2.72	0.10	2.86	2.52	2.68	2.73	2.79
5	1	3	1	50	2.67	0.08	2.84	2.56	2.60	2.66	2.71
6	1	3	2	50	2.72	0.09	2.86	2.52	2.66	2.73	2.80
7	2	1	1	10	3.03	0.16	3.31	2.88	2.90	2.96	3.21
8	2	1	2	10	3.00	0.13	3.20	2.87	2.91	2.95	3.14
9	2	2	1	18	2.99	0.10	3.18	2.85	2.91	2.99	3.08
10	2	2	2	20	3.01	0.11	3.23	2.87	2.91	3.03	3.09
11	2	3	1	30	2.99	0.09	3.15	2.86	2.90	2.99	3.06
12	2	3	2	30	3.00	0.12	3.25	2.87	2.88	2.95	3.11

FINAL LOG DATA

OBS	S	D	R	N	MEAN	STD	MAX	MIN	Q1	MED	Q3
1	1	1	1	0							
2	1	1	2	4	3.24	0.40	3.81	2.91	2.97	3.12	3.52
3	1	2	1	4	3.26	0.22	3.38	2.94	3.15	3.37	3.37
4	1	2	2	2	3.50	0.06	3.54	3.46	3.46	3.50	3.54
5	1	3	1	3	3.36	0.37	3.78	3.06	3.06	3.24	3.78
6	1	3	2	7	3.26	0.34	3.77	2.84	2.94	3.22	3.58
7	2	1	1	3	3.33	0.13	3.47	3.21	3.21	3.32	3.47
8	2	1	2	2	3.66	0.18	3.79	3.54	3.54	3.66	3.79
9	2	2	1	1	3.58		3.58	3.58	3.58	3.58	3.58
10	2	2	2	2	3.41	0.66	3.88	2.95	2.95	3.41	3.88
11	2	3	1	1	3.04		3.04	3.04	3.04	3.04	3.04
12	2	3	2	2	3.30	0.26	3.48	3.12	3.12	3.30	3.48

FIGURE A1

BOX PLOTS OF WEIGHTS FOR THE 0-3 WEEK EXPERIMENTS

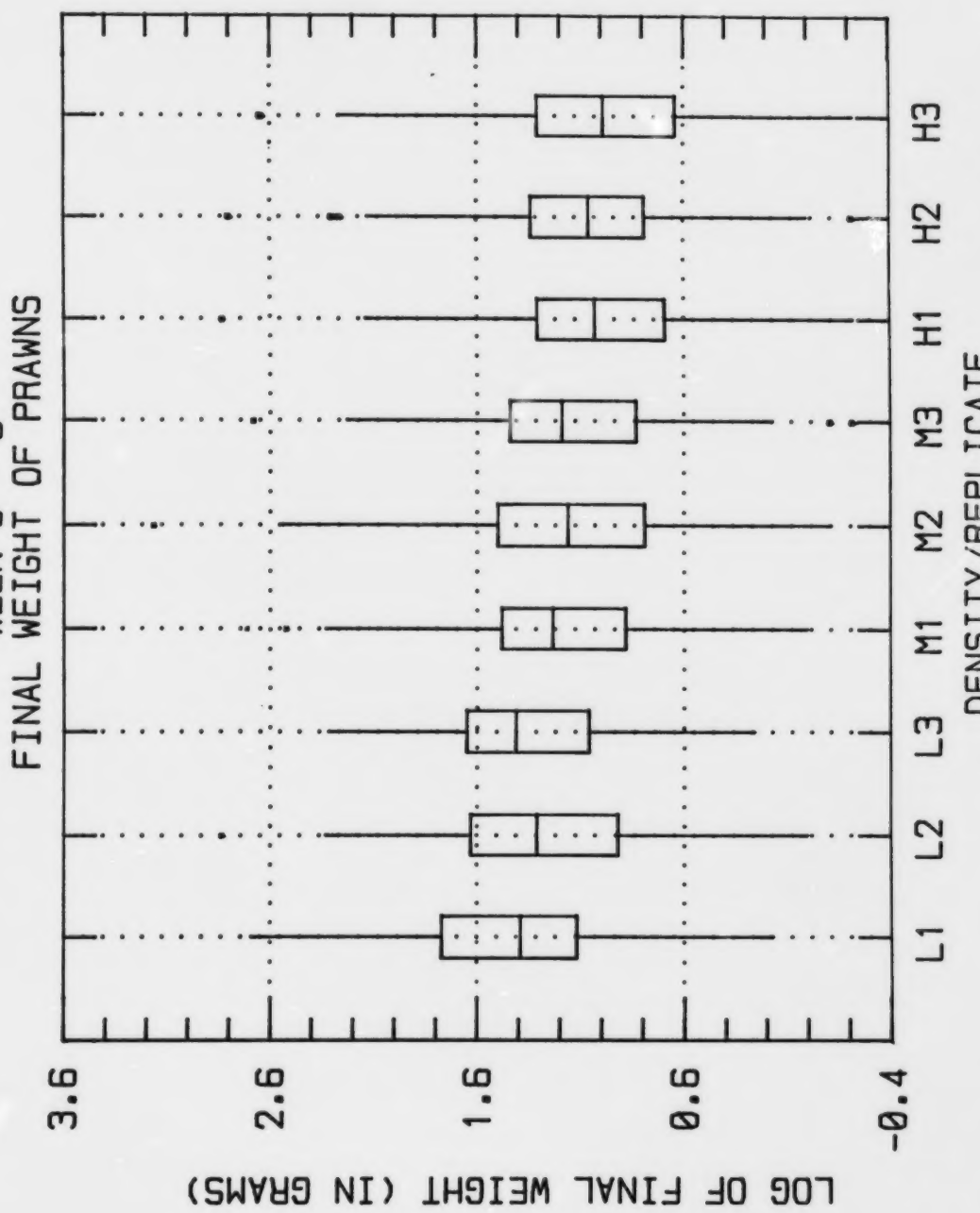
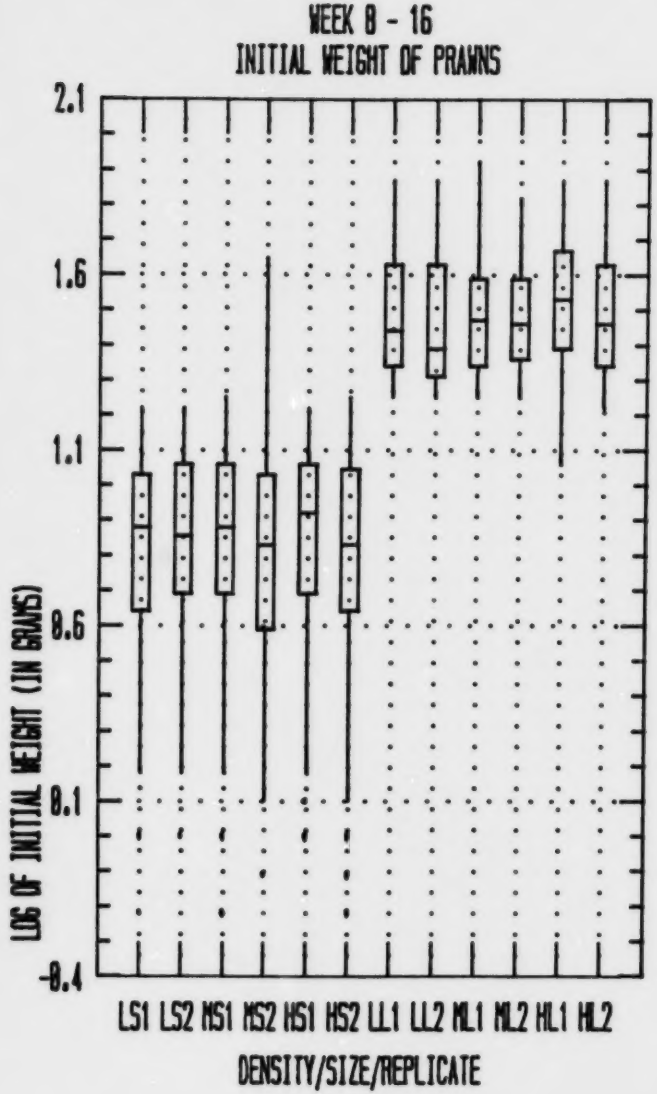


FIGURE A2

BOX PLOTS OF WEIGHTS FOR THE 8-16 WEEK EXPERIMENTS



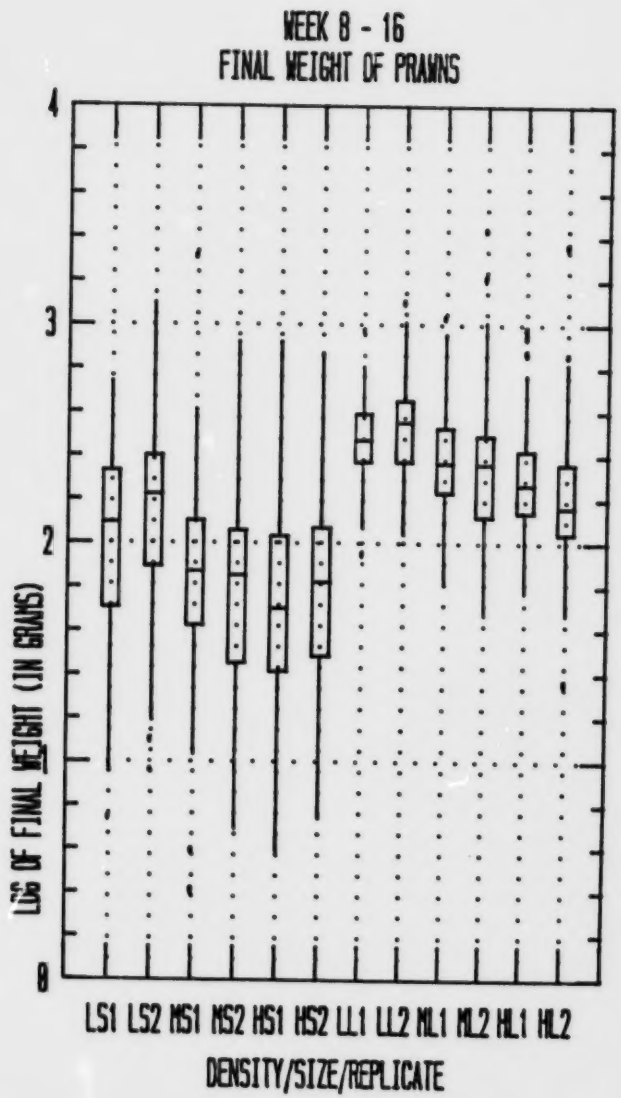
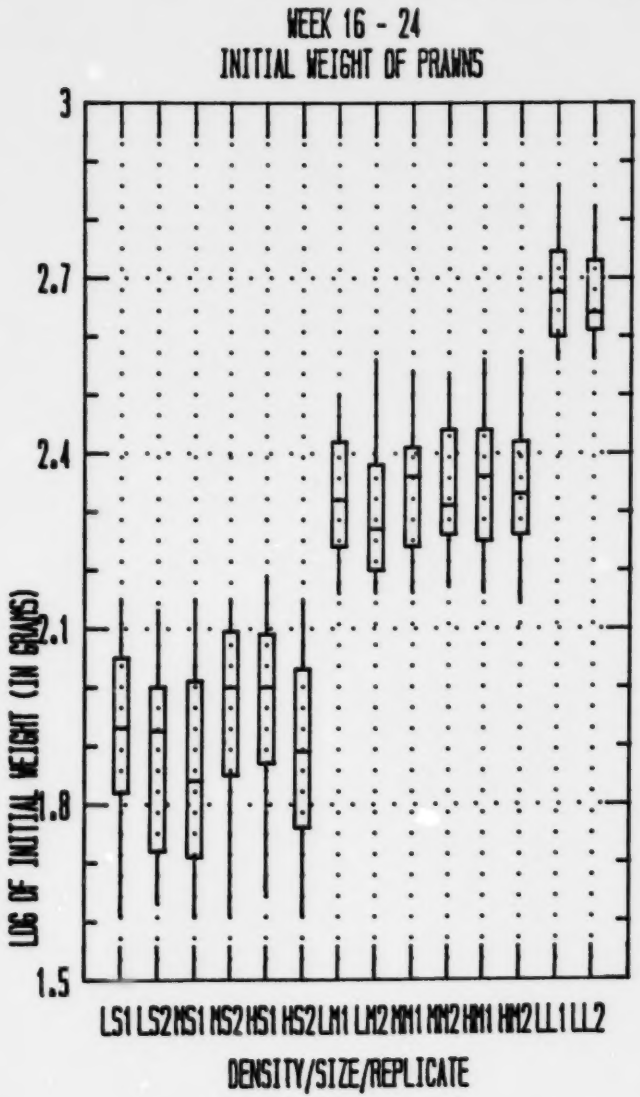


FIGURE A3

BOX PLOTS OF WEIGHTS FOR THE 16-24 WEEK EXPERIMENTS



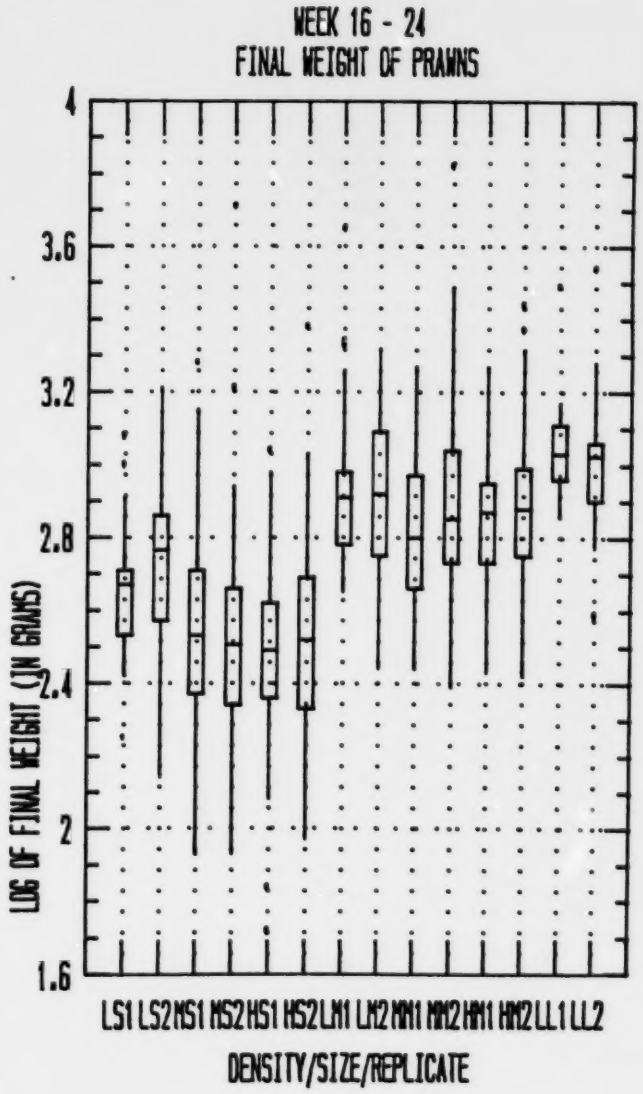


FIGURE A4

BOX PLOTS OF WEIGHTS FOR THE 24-32 WEEK EXPERIMENTS